

SUBJECT: Opportunities for a Short
Cross Range Orbiter to Return
to the Prime Landing Site.
Case 900

DATE: January 4, 1971

FROM: R. K. Chen

ABSTRACT

The ability of a short cross range (approximately 200 nm) Space Shuttle Orbiter to return to its prime landing site (by definition, its launch site) after a logistics supply mission to the Space Station is examined. The specific cases analyzed assumes that (1) the Space Station was launched from KSC into a 55° inclination circular orbit with altitudes ranging from 242 to 270 nm, (2) the assumed prime landing sites for the Orbiter are either KSC, Holloman AFB, or Edwards AFB, (3) a direct return trajectory is used by the Orbiter without any intermediate phasing orbit(s), and (4) a capability to return within 24 hours is desired.

The results show that, with the exception of the 270 nm altitude orbit, the short cross range Orbiter would not always be able to return directly to the prime landing sites assumed within 24 hours. An Orbiter with 400 nm cross range capability is needed for the KSC and Edwards AFB sites, and an Orbiter with 500 nm cross range capability is needed for the Holloman AFB landing site. The 270 nm altitude orbit is an exception because its ground tracks repeat almost exactly after every 14 revolutions. In this case the short cross range Orbiter could return to KSC and Edwards AFB every 14 revolutions (a little less than a day), and by extending the cross range capability to about 240 nm, the same would be true for Holloman AFB. The 270 nm altitude orbit, however, does not appear to be attractive for Earth Resources experiments, as its 14 revolutions repeatable ground track would preclude the observation opportunity of a large portion of the Earth.

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MEMORANDUM FOR FILE

Introduction

The cross range capability of the Space Shuttle is pertinent to the Earth based support that needs to be provided for its use. Two versions of the Orbiter portion of the Space Shuttle are being considered in the Phase B studies, (1) a long cross range design of approximately 1500 nm and (2) a short cross range design of approximately 200 nm. The cross range capability of the Orbiter affects its recovery operation, specifically, the time to return from orbit to a particular landing site. This memorandum examines the ability of a short cross range Orbiter, on a logistics supply mission to the Space Station, to return directly (without intermediate phasing orbit) to the prime landing site (by definition, the launch site) within 24 hours.

Assumptions

Space Station - The Space Station is assumed to have been launched from KSC into a circular orbit with a 55° inclination. The altitude of the orbit is between 240 and 270 nm (the two Space Station Phase B contractors, MDAC and NAR, have picked 242 and 270 nm respectively). It is also assumed that, with the exception of station keeping, no orbital change takes place.

Space Shuttle - Three typical shuttle launch and recovery sites are considered, KSC, Holloman Air Force Base, and Edwards Air Force Base. The coordinates of these sites are:

	<u>Longitude</u>	<u>Latitude</u>
KSC	279.3066°E	28.5083°N
Holloman AFB	253.8333°E	32.8333°N
Edwards AFB	242.1677°E	34.8333°N

Another assumption made is that the Orbiter returns from the Space Station to the landing site directly without any intermediate phasing orbit(s).

Analysis

The analytical tool used is an MSFN station coverage computer program; the ground stations in this case are the three landing sites. The cross range capabilities of the Orbiter are simulated by adjusting the elevation angles of the ground stations so that the radius of the coverage cones at the desired Space Station altitudes correspond to the cross range (measured on Earth surface) capabilities of the Orbiter. The following altitude and cross range combinations are used:

<u>Altitude</u>	<u>Cross Range (elevation angle)</u>
242 nm	350 nm (32.77°), 400 nm (29.36°), 450 nm (26.55°), 500 nm (24.18°)
245 nm	350 nm (33.07°), 400 nm (29.64°), 450 nm (26.81°), 500 nm (24.43°)
250 nm	350 nm (33.57°), 400 nm (30.11°), 450 nm (27.25°), 500 nm (24.89°)
255 nm	350 nm (34.05°), 400 nm (30.57°), 450 nm (27.68°), 500 nm (25.24°)
260 nm	350 nm (34.54°), 400 nm (31.01°), 450 nm (28.11°), 500 nm (25.65°)
265 nm	350 nm (35.01°), 400 nm (31.48°), 450 nm (28.54°), 500 nm (26.04°)

Whenever the ground stations, the landing sites in this case, make contacts within the coverage cones, return opportunities exist for the particular cross ranges simulated.


A pertinent characteristic of the Space Station orbits is the repeatability of its ground track; i.e., the period it takes for the Space Station to come back to the same area over the Earth. The approximate repeatability of the selected orbits are:

<u>Altitude</u>	<u>Aprox. No. of Revolu- tions for Repeatable Earth Coverage Pattern</u>
242 nm	85
245 nm	99
250 nm	367
255 nm	324
260 nm	253
265 nm	533
270 nm	14

An orbital revolution is defined as the period for the orbital ground track arriving at a particular longitude; the period for each revolution at these altitudes is approximately 100 minutes. Every orbit exhibits a repeatable coverage pattern so that after some number (N) revolutions, the ground track of the spacecraft would be the same geometrically for the nth revolution as $n^{\text{th}} + N$ revolution. Knowing the repeatability of the orbit behavior reduces the number of computer runs needed for the analysis, exact repeatability of the orbits are not calculated; instead their approximations are used. The approximations are good to within 0.50° ground tracks repeatability.

The 270 nm altitude orbit is of special interest. This orbit repeats almost exactly every 14 revolutions or in a little less than a day. Therefore, a return opportunity can be guaranteed for selected sites once a day; in particular, this is true for Space Station launch site at KSC. The same orbital characteristics, however, would prevent a return to sites that are geometrically located between the successive ground tracks at a distance greater than the cross range capability of the Orbiter. One such site is Holloman AFB from which a 200 nm cross range Orbiter would be unacceptable but a 240 nm cross range Orbiter would be acceptable.

The 270 nm orbit does not appear attractive for Earth Resources experiments unless very wide angle, high resolution cameras are developed. The spacing between successive ground tracks is about 1400 nm and since the ground tracks repeats almost exactly every 14 revolutions, the only way to obtain complete coverage of the Earth is to have a wide angle camera covering 1400 nm at 270 nm altitude. The camera planned for



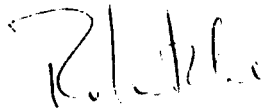
Earth Resources Experiments Package for the Skylab mission only covers roughly 80 nm from a 230 nm altitude.

Results

The results of the computer runs are summarized in Table I. For each altitude-cross range combination, return opportunities exceeding 24 hours are given based on the period for coverage repeatability. Hence at a Space Station orbit of 250 nm altitude, it takes approximately 615 hours for the coverage pattern to repeat; within this 615 hours, there will be two return opportunities exceeding 24 hours for the KSC launch site for an Orbiter with 350 nm cross range capability. The length of the two periods are about 33 hours each. Similarly, for Holloman AFB three periods of return opportunity exceed 24 hours (one of 87 hours and two of 64 hours). If the cross range capability of the Orbiter were 400 nm, a 24 hours direct return opportunity exists for both KSC and Edwards AFB but not for Holloman AFB. A 500 nm cross range capability is needed for the Orbiter for its direct return to Holloman AFB within any 24 hour period.

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R. K. Chen

Orbit Altitude (nm)	Approx. Period for Coverage to Repeat (Hrs)	Orbiter Cross Range Capability → Shuttle Launch Site →	350 nm			400 nm			450 nm	500 nm
			MILA	HOL	EDW	MILA	HOL	EDW		
242	142		33hr	64hr	*	*	40hr	*	*	*
245	165		*	64	40hr	*	63.5	*	*	*
250	615		33 33	87 64 64	40 40	*	40 64 64	*	40 40 40	*
255	544		33 33	87 110	40	*	64 64	*	40 40	*
260	426		33	110	*	*	87	*	64	*
265	899		*	253	40	*	159	*	64	*
270	24		*	*	*	*	*	*	*	*

* Means one or two return opportunity exists.

SPACE SHUTTLE WORST RETURN OPPORTUNITIES
FOR DIFFERENT CROSS RANGE CAPABILITIES

TABLE 1